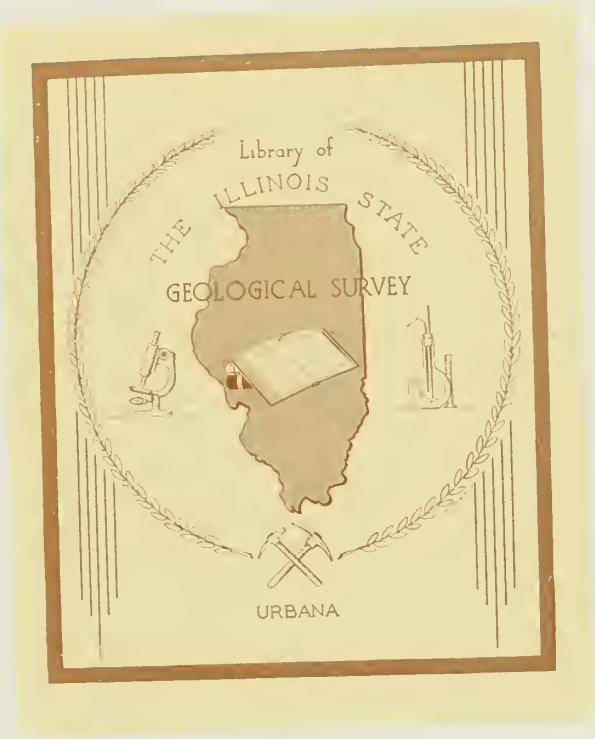

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ILLINOIS CLAYS AS BINDERS FOR IRON ORE PELLETS

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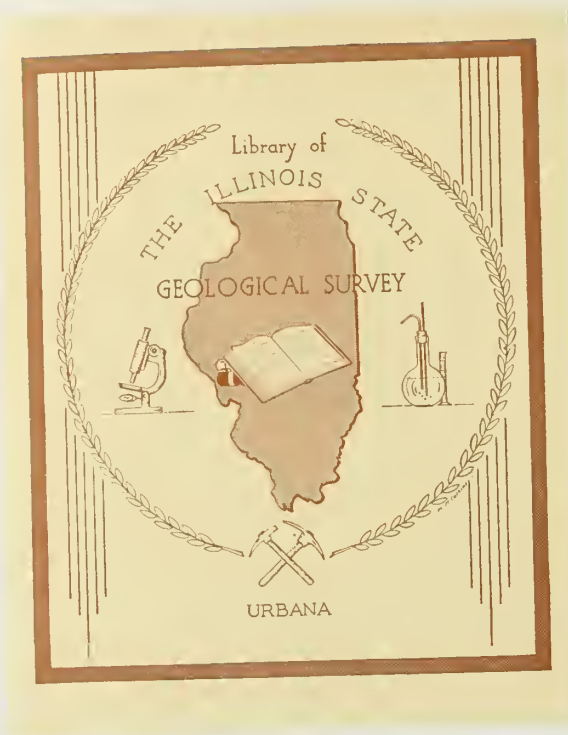
A B S T R A C T

Clays from seven outcrops in west-central and southern Illinois were evaluated as binders for Missouri iron ore pellets. Experimental hand-molded pellets were tested for their green, dry, and fired strengths, and compared with pellets in which Wyoming bentonite was used as binder.

Illinois clays were tested in three forms, (1) as finely ground, crude material, (2) after air classification, and (3) as the minus-2-micron product resulting from water dispersion and subsequent flocculation, drying, and regrinding.

In general, the crude Illinois clays imparted to pellets somewhat lower green and dry strengths but greater fired strength than did Wyoming bentonite. Air classification of the clays resulted in greater pellet strength, both before and after firing, than was obtained in most cases with the crude clays. The water-dispersed clays, which are thought to be practically pure clay mineral, caused even greater increase in pellet strength.

The test results indicate strongly that properly prepared Illinois clays can be used for pelletizing iron ore.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ILLINOIS CLAYS AS BINDERS FOR IRON ORE PELLETS

INTRODUCTION

Iron ores that have been finely pulverized during processing are usually pelletized to make them suitable for charging to blast furnaces.

The pellets generally are made by adding 1 percent or less of finely ground bentonite to the fine ore and rolling the mixture into balls, three-eighths to five-eighths of an inch in diameter, in a pelletizing drum or disc. The moist, green pellets are transferred by belt to a vertical, up-draft furnace, or other heating device, and fired at a temperature of about 2400° F. They are quickly dried and sintered, forming hard pellets that can be shipped and later charged into a blast furnace with minimum breakage.

The bentonite is used to give stability to the green pellets during initial handling and firing and to impart a fired strength that will permit the pellets to be transported and handled. Most of the bentonite currently used comes from Wyoming.

If an Illinois clay could be used successfully in place of the Wyoming bentonite in the midwestern area, the cost of the pellets might be reduced because of lower freight costs.

LABORATORY TESTS

To test the ability of Illinois clays to replace Wyoming bentonite, we simulated in our laboratory the pelletizing procedure described above and used Missouri ore prepared by the Meramec Mining Company to mix with various clays. Green, dry, and fired strengths of pellets containing clays for binder were determined.

Clays from Illinois were mixed with the moist, beneficiated ore in amounts of 1 percent and 0.75 percent of ore weight. Water was added when required to bring the moisture content to about 9.5 percent, at which point good balling could be obtained. Similar mixtures of the Missouri ore and Wyoming bentonite were made to use as a standard for comparison. These mixtures of ore and binders were hand formed into spherical pellets of commercial size and tested.

Green and dry strengths were determined on laboratory scales. The pellets were tested when freshly made and at a range of moisture values as they dried. Dry pellet strength was determined after there was no further

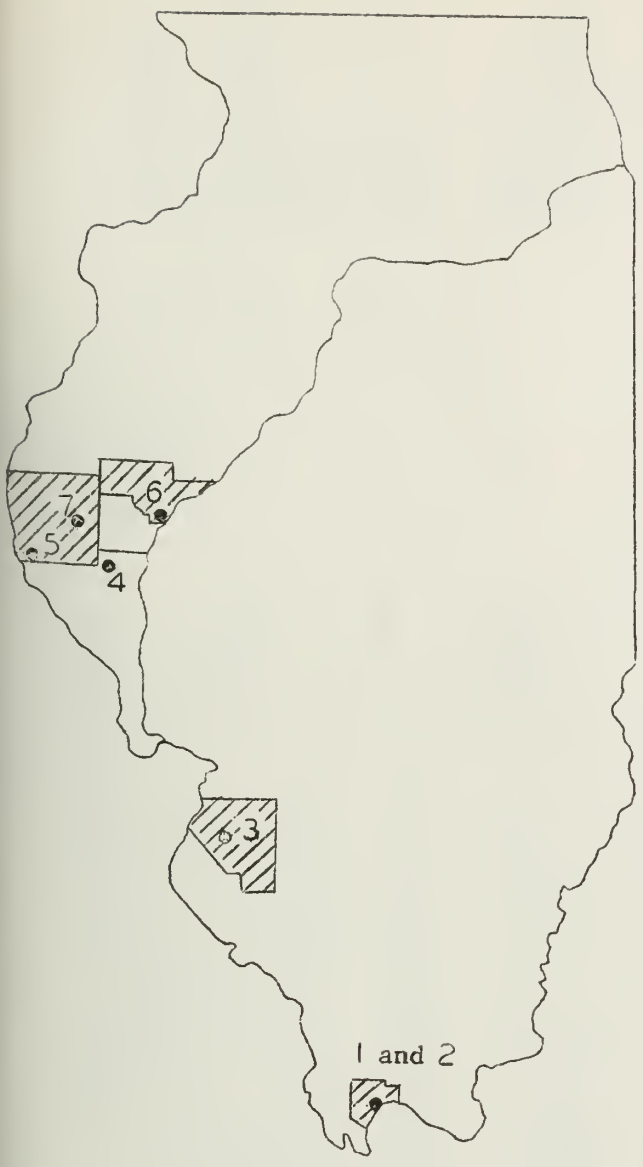

Fig. 1 - Location of deposits sampled.

loss of weight at room temperature. At least five pellets were crushed for each of these strength determinations and the results averaged. More pellets were tested if results were not consistent.

To obtain fired strength, 50 to 60 freshly made pellets were placed in a drying oven at 350° F for 15 minutes and then immediately transferred to an electrically heated muffle furnace, previously heated to 2400° F. This temperature was maintained for 30 minutes, after which the power was cut off and the pellets were allowed to cool slowly to about 400° F before being removed from the furnace. The cooled pellets were tested for compression strength in a Carver-type press. Fifty pellets were broken for each clay-ore mixture tested.

ILLINOIS CLAYS TESTED

Channel samples of clays were collected from seven outcrops in west-central and southern Illinois. Details of location and the clay mineral components of each sample are listed in table 1. Figure 1 shows the approximate location of each deposit sampled.

Samples were prepared by grinding the clay through an 8-inch hammer mill that contained a grinding screen with .01 by $^{15}/_{32}$-inch openings. Ground samples were divided into three portions. The first portion was tested without further preparation; the second was passed through an air classifier, which eliminated almost all particles larger than 35 microns; and the third was dispersed in water, after which the minus-2-micron clay fraction was siphoned off, settled with a flocculating agent, filtered, dried, and reground. Wyoming bentonite used for comparison was a commercially prepared minus-200-mesh grade.

The clay deposits sampled do not exhaust the varieties of clay available in Illinois, but were selected because they are among the clays likely to give satisfactory results and they occur nearest to the Missouri ore deposits. Additional deposits of similar clays are present in the vicinity of all the deposits sampled and in other parts of the state.

TABLE 1 - CLAY MATERIALS TESTED

Clay sample	County	Location: Quarter	Sec.	T.	R.	Age	Thickness (ft)	Overburden	Clay materials (parts in 10)	
1. Porters Creek Fm. (yellow weathered clay) **(IGS sample FE 113)**	Pulaski	NE SE (southeast of Olmsted on west cutbank of Ohio River)	27	15S	1E	Tertiary	20	20-40	Montmorillonite and mixed-layer Other	9 1
2. Porters Creek Fm. (blue clay) (IGS sample 2102)	Pulaski	NE SE (directly under yellow clay)	27	15S	1E	Tertiary	30-50	40-60	Montmorillonite Other	9 1
3. Underclay of Herrin (No. 6) Coal, Carbondale Fm. (IGS sample 2101)	St. Clair	(Midwest Mine, Peabody Coal Co.)	6	1S	8W	Pennsylvanian	3-4	-	Mixed-layer Illite Chlorite plus kaolinite	5 4 1
4. Baylis Fm. (IGS sample 1775)	Pike	SE SW NE (north and south roadcuts and east-west county road west of farm house)	29	3S	4W	Cretaceous	8 exposed	thin	Montmorillonite Illite Kaolinite	7 2 1
5. Kansan till (IGS sample P 1746)	Adams	SE SE SW (northeast roadcut west of church)	9	3S	8W	Pleistocene	25	0-40	Montmorillonite and mixed-layer Illite Kaolinite	8 1 1
6. Kansan till (IGS sample 2043)	Schuyler	near cen. NE (northeast roadcut bank in southwest valley wall of Illinois River above where road crosses tributary)	23	1N	1W	Pleistocene	5	20-40	Montmorillonite and mixed layer Illite Kaolinite	6 3 1
7. Illinoian lake clay (IGS sample P 1834)	Adams	SW SE SE (5 miles east of Columbus on new road at McKee Creek)	14	1S	6W	Pleistocene	15	6	Montmorillonite and mixed-layer Illite Kaolinite	8 1 1

RESULTS OF TESTS

Strength characteristics of all experimental pellets produced are summarized in tables 2, 3, and 4. Fired strength is indicated by the percentage of pellets that broke (1) under a load of more than 850 pounds, (2) between 850 and 350 pounds, and (3) at less than 350 pounds. The average load required to break 50 pellets also is given.

Green strength is shown as the load in ounces required to crack green pellets at 9 percent, 7.5 percent, and 5 percent moisture. These values are taken from curves plotted from the experimental data. Dry strength is shown as the average load in ounces required to crack the air-dried pellets.

Pellets Containing Crude Clays

In general, the addition of 1 percent of the crude, ground Illinois clays gave green strength to pellets that was roughly equivalent to that produced by adding 0.75 percent of Wyoming bentonite (table 2). None of the crude Illinois clays gave dry strength equal to the +48 ounces obtained with bentonite, the closest being clays 1 and 7 from Pulaski and Adams Counties, which gave dry strengths of 36 ounces.

Fired strength of the pellets made with crude Illinois clays for binder was consistently greater than that of pellets made with Wyoming bentonite. Thirty-two percent of the pellets made with Illinois crude clays withstood an applied load of 850 pounds, whereas only 14 percent of the pellets made with bentonite withstood that load. Approximately the same percentage of crude clay and bentonite pellets broke at less than 350 pounds load. Six of the seven clays tested produced stronger pellets when 0.75 percent of clay was used as a binder than when 1 percent of clay was used.

Pellets Containing Air-Classified Clays

The green and dry strengths of pellets containing air-classified clays (table 3) were higher in every instance than those of the corresponding pellets made with crude clays. Pellets containing 0.75 percent of air-classified clays developed greater green strength in every case than was developed with the same percentage of Wyoming bentonite.

The average fired strengths of pellets containing the seven air-classified clays were higher than average fired strengths for the pellets made with corresponding crude clays in 9 of the 14 tests made. The percentage of pellets breaking at under 350 pounds load was inconsistent; air classification appeared to be beneficial in this respect to four of the clays tested.

TABLE 2 - STRENGTH OF IRON ORE PELLETS MADE WITH BENTONITE AND WITH CRUDE ILLINOIS CLAYS — DRIED AND GROUND

Clay binder			Strength when fired at 2400° F				Green strength			Dry strength
			Percentage of pellets breaking at applied load (lbs)			Average load to break	Average load to break (oz)			Average load to break
No.	Source	% Added	Plus 850	850 to 350	Minus 350	(lbs)	9% M	7.5% M	5% M	(oz)
Wyo. bentonite		1.00	17	76	7	540	15.0	18.3	17.5	+48
		0.75	10	81	9	560	12.9	13.8	12.3	+48
1.	Porters Creek Fm. (yellow clay) Pulaski Co.	1.00	38	58	4	750	10.7	14.2	12.8	36.3
		0.75	51	41	8	790	9.0	13.3	11.8	25.3
2.	Porters Creek Fm. (blue clay) Pulaski Co.	1.00	42	51	7	760	11.0	13.5	14.5	26.5
		0.75	50	41	9	800	9.2	11.7	12.5	22.2
3.	Underclay of Herrin (No. 6) Coal St. Clair Co.	1.00	34	62	4	710	10.7	13.7	13.5	15.5
		0.75	40	56	4	820	9.5	11.5	11.0	12.7
4.	Baylis Fm. (Cretaceous clay) Pike Co.	1.00	19	64	17	610	10.8	14.2	12.7	26.5
		0.75	42	41	17	720	10.7	13.0	11.2	20.2
5.	Kansan till Adams Co.	1.00	17	75	8	640	10.5	13.5	13.0	30.2
		0.75	12	81	7	950	9.7	11.7	12.5	24.0
6.	Kansan till Schuyler Co.	1.00	22	67	11	640	10.0	12.3	13.0	19.0
		0.75	29	60	11	700	9.5	12.0	11.5	17.0
7.	Illinoian lake clay Adams Co.	1.00	29	62	9	660	11.0	13.2	13.0	36.0
		0.75	28	59	13	640	12.0	11.7	10.2	30.0

TABLE 3 - STRENGTH OF IRON ORE PELLETS
MADE WITH AIR-CLASSIFIED CLAYS

Clay binder			Strength when fired at 2400° F				Green strength			Dry strength
			Percentage of pellets breaking at applied load (lbs)			Average load to break	Average load to break (oz)			Average load to break
No.	Source	% Added	Plus 850	850 to 350	Minus 350	(lbs)	9% M	7.5% M	5% M	(oz)
1.	Porters Creek Fm. (yellow clay) Pulaski Co.	1.00	44	43	13	750	13.0	16.4	15.7	+48
		0.75	57	32	11	830	12.0	15.0	14.0	43
2.	Porters Creek Fm. (blue clay) Pulaski Co.	1.00	64	28	8	890	15.2	16.2	17.0	33.5
		0.75	84	14	2	1060	15.5	15.0	15.5	32.2
3.	Underclay of Herrin (No. 6) Coal St. Clair Co.	1.00	32	52	16	620	13.5	16.5	15.5	24
		0.75	50	36	14	690	13.7	15.5	14.0	22
4.	Baylis Fm. (Cretaceous clay) Pike Co.	1.00	42	42	16	730	14.0	16.0	14.5	46
		0.75	40	40	20	710	13.2	14.7	14.0	37
5.	Kansan till Adams Co.	1.00	78	18	4	950	14.0	15.0	14.8	+48
		0.75	58	42	0	800	13.6	14.3	13.1	40
6.	Kansan till Schuyler Co.	1.00	76	20	4	1010	15.0	16.8	16.5	45
		0.75	60	36	4	800	13.5	15.2	14.5	35
7.	Illinoian lake clay Adams Co.	1.00	64	30	6	910	15.0	15.3	15.0	+48
		0.75	72	24	4	950	14.2	14.8	14.2	+48

TABLE 4 - STRENGTH OF IRON ORE PELLETS
MADE WITH MINUS-2-MICRON CLAY

Clay binder			Strength when fired at 2400° F				Green strength			Dry strength
No.	Source	% Added	Percentage of pellets breaking at applied load (lbs) Plus 850	850 to 350	Minus 350	Average load to break (lbs)	Average load to break (oz) 9% M	7.5% M	5% M	Average load to break (oz)
1.	Porters Creek Fm. (yellow clay) Pulaski Co.	1.00	57	41	2	830	13.6	15.6	18.1	+48
		0.75	53	45	2	800	11.7	14.8	15.8	+48
2.	Porters Creek Fm. (blue clay) Pulaski Co.	1.00	80	20	0	1020	16.0	17.0	17.8	46
		0.75	84	14	2	1030	15.5	16.5	17.0	43
3.	Underclay of Herrin (No. 6) Coal St. Clair Co.	1.00	60	38	2	890	15.0	17.5	17.0	+48
		0.75	36	62	2	770	14.0	15.7	14.2	+48
4.	Baylis Fm. (Cretaceous clay) Pike Co.	1.00	90	8	2	1140	15.2	16.5	16.0	+48
		0.75	80	12	8	1030	14.5	15.5	14.5	+48

Pellets Containing Water-Dispersed Clays

As a final step in the evaluation of these Illinois clays, four water-dispersed clays, thought to be practically pure clay mineral, were tested (table 4) for their binding properties in Meramec ore pellets. Although this degree of beneficiation could probably not be obtained commercially at a competitive cost, it does represent the ultimate goal of efficient processing.

The green and dry pellet strengths developed by each clay in this group were higher than those obtained with the corresponding crude or air-classified clays. Similarly, the average fired strength was appreciably higher in 6 of the 8 tests made. The percentage of pellets that broke at less than 350 pounds load was consistently low, and in only one test did this amount to more than 2 percent of the total.

SUMMARY

Laboratory tests indicate that certain Illinois clays can be successfully used as binders in production of iron-ore pellets for blast furnace use.

Pellets of Missouri ore containing crude Illinois clays when fired at 2400° F developed greater strength than pellets made with equal percentages of Wyoming bentonite as a binder. About 1 percent of clay was required, however, to give the pellets a green strength equivalent to that produced by 0.75 percent of bentonite. Pellet strength is generally increased by clay beneficiation designed to concentrate clay mineral in the product. A saving in freight costs should result from replacing bentonite with Illinois clays in the midwestern area.